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REPRODUCED AT GOVERNMENT EXPENSE

GENERALIZED RADOME BSE CHARACTERIZATION
USING SUPERPOSITION TECHNIQUES

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INTRODUCTION

Measurement of radome boresight error response to both polarization and gimbal angle variations can result in excessively long measurement times if a large number of incident polarizations are to be tested. Instead, by measuring the antenna radome system response to two orthogonal polarizations, and by using electro-magnetic superposition, it is possible to completely characterize the antenna/radome BSE response as a function of any arbitrary incident polarization.

Agreement between calculated and measured BSE for multiple linear incident polarization states is excellent. The method can also be applied to obtain multiple polarization antenna patterns in the presence of a radome.

This paper will focus on the details of implementing the generalized radome BSE characterization in the Bedford Automated Test Facility and will compare measured and superpositioned data.

A significant cost and time saving results from the use of superposition methods in radome testing.

ANALYSIS

Polarization Considerations in BSE Measurements and Calculations

Radome boresight error (BSE) contains the following constituent specifications,

1) Incident field polarization, $\underline{E_i} = E_x\hat{x} + E_y\hat{y}$

2) Seeker antenna polarization, $\underline{P} = P_x\hat{x} + P_y\hat{y}$

and

3) Radome complex transfer function, $\underline{X}$

where 3) has finite cross coupling terms that permit the seeker to respond to an incident polarization spatially orthogonal to the seeker nominal polarization, and in general E_x, E_y, P_x, P_y are complex quantities. For nominal vertically linearly polarized missile systems $E_y = P_y = 1$ and $E_x = P_x = 0$.

The radome transfer matrix consists of elements X_{ij} which are responses (in the presence of the radome) in the i-polarized channel for j-polarization incident on the radome (receive formulation of radome problem assumed). X_{ij}

for each complex gimbal angle are given analytically by the reaction integral equation (Reference 1) or can be measured with orthogonally polarized transmit antennas ($E_y = 1$, $E_x = 0$ and $E_y = 0$, $E_x = 1$).

Finally, the response V for arbitrary incident and antenna polarization is given by,

$$V = S_x P_x + S_y P_y$$

where

$$\begin{pmatrix} S_x \\ S_y \end{pmatrix} = \underline{X} \begin{pmatrix} E_x \\ E_y \end{pmatrix}$$

and the monopulse BSE may be derived from the delta over sum voltages, the monopulse sensitivity (co-pol), and the polarization dependent antenna null shift. True BSE would include a polarization dependent monopulse sensitivity as well.

Test Station Application

From a measurement point of view the radome transfer matrix, $\underline{X}$. can be obtained by measuring antenna responses, in the presence of the radome, for two orthogonal linear transmit signals. In order to avoid receiver instabilities associated with large noise to signal ratios for the cross channel state (e.g., $E_X = 1$ and $P_X = 0$ conditions) the orthogonal states chosen are

$$E_{x_o} = \pm\ 0.707$$

$$E_{y_o} = 0.707$$

for a typical

$$P_x = 0$$

$$P_y = 1$$

antenna. In this instance the radome transfer matrix $\underline{X}$ becomes,

$$\underline{X} = \underline{T}\ \underline{X}'\ \underline{T}^{-1}$$

where,

$\underline{T}$ = coordinate transform for 45° axis rotation

and

$\underline{X}'$ = measured antenna responses in the presence of the radome.

A secondary potential problem to superposition measurements common to some (phase meter range $\pm\pi$) automated test equipment is a nearly 2π radians phase transition experienced in an antenna channel (Δ pitch, Δ yaw, or Σ) voltage measurement which is computer sampled. If the computer samples voltage during phase transitions (during gimballing) and computes BSE,

$$BSE = \text{Real}\left\{\frac{V_\Delta / V_\Sigma}{S_\Delta / S_\Sigma}\right\}$$

where

S_Δ, S_Σ = monopulse sensitivities

a BSE as shown in Figure (1) could result. The probability of these transitions occuring increases when the antenna is receiving out of its nominal polarization plane. Retesting with π radians phase shift will relocate the indeterminant phase points in gimbal space. It is then possible to piece together the correctly sampled curve portions to define BSE over the desired gimbal angle range (see Figure (2)). This time-consuming retest process has been practically eliminated using a specially developed "deglitching" computer program.

The new approach operates directly on the antenna port voltages. First, voltage arguments (phases) are differentiated twice with respect to gimbal angle. Then, based on $\partial^2\phi/\partial G^2$, voltage points are retained or deleted. Next, gaps between retained voltage points are filled by fitting a complex third order polynomial to adjacent point pairs (Lagrange interpolation formulas). The method can be generalized to any order polynomial should future data indicate that further refinement is necessary.

MEASURED DATA

Data Sets

Global (off-axis, 32 cuts) BSE data were taken on an X-band radome of fineness ratio 2.50 for two conditions

1) $\pm$ 45° plane basis data, i.e., $E_x = \pm\ 0.707$, $E_y = 0.707$

and

2) linear BSE for polarization angles (α) zero to 87°

For comparison with data set (2) the data in set (1) were combined or superimposed, using the techniques outlined in section 2.1. The comparison plots are given in Figure 3. Good agreement exists between the measured and sythesized BSE multiple polarization data sets.

Data Reduction

The multiple polarization equations used to reduce test station data can be expressed in the following summary form for a y-polarized linear antenna:

$$V = aV_{x\text{-pol}} + bV_{co\text{-pol}}$$

where

$$V_{x\text{-}pol} = X_{21}, \quad a = E_x$$

$$V_{co\text{-}pol} = X_{22}, \quad b = E_y$$

and the complex coefficients a, b define any linear, circular or elliptic polarization state using standard (Gamma) formulations (Reference 2).

CONCLUSION

A general method of calculating multiple polarization BSE data based on only two measurements has been developed. Comparison between superimposed orthogonal measured data and measured linear multiple polarization BSE confirms the applicability of the method from a radome test and evaluation viewpoint. The intended use of the characterization technique is to economize testing time required to characterize the polarization dependence of BSE.

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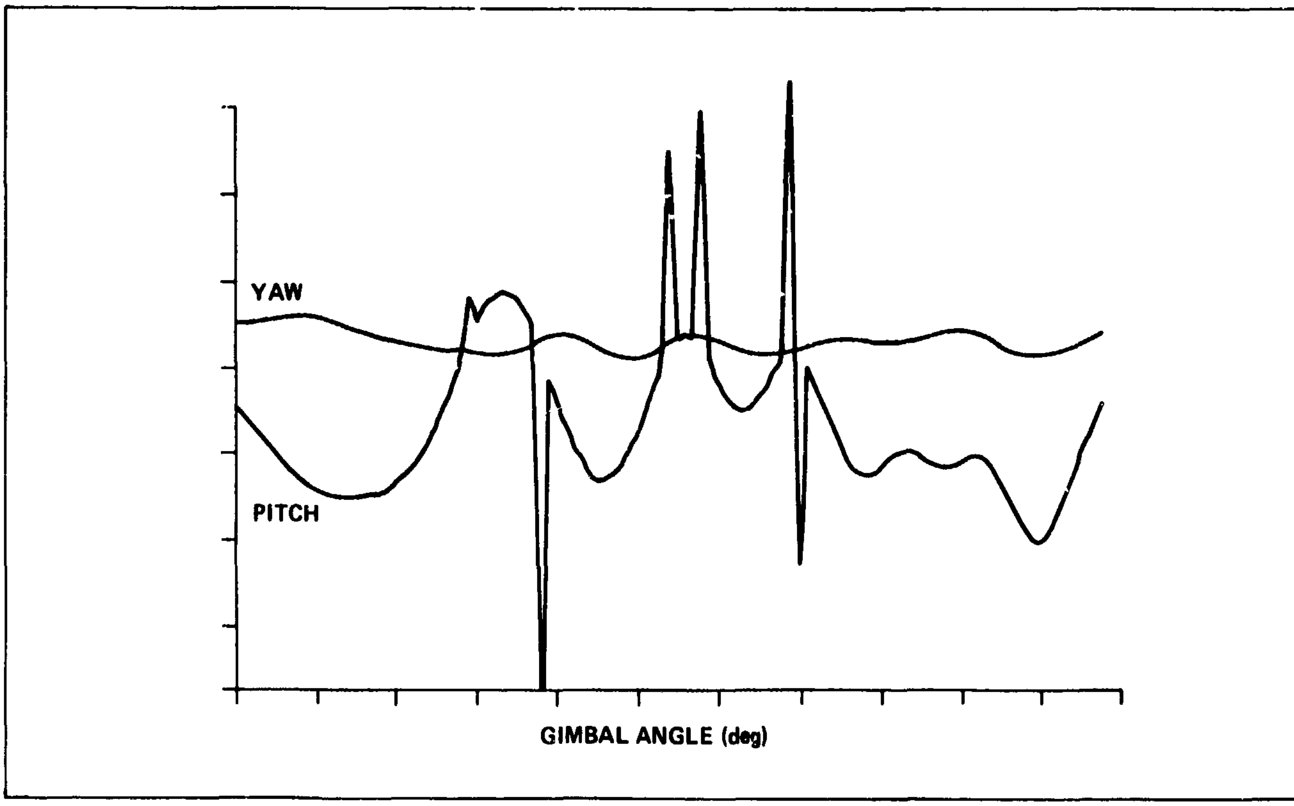

Figure 1. BSE vs Gimbal Angle without Computer Sampled Voltage Phase Corrections

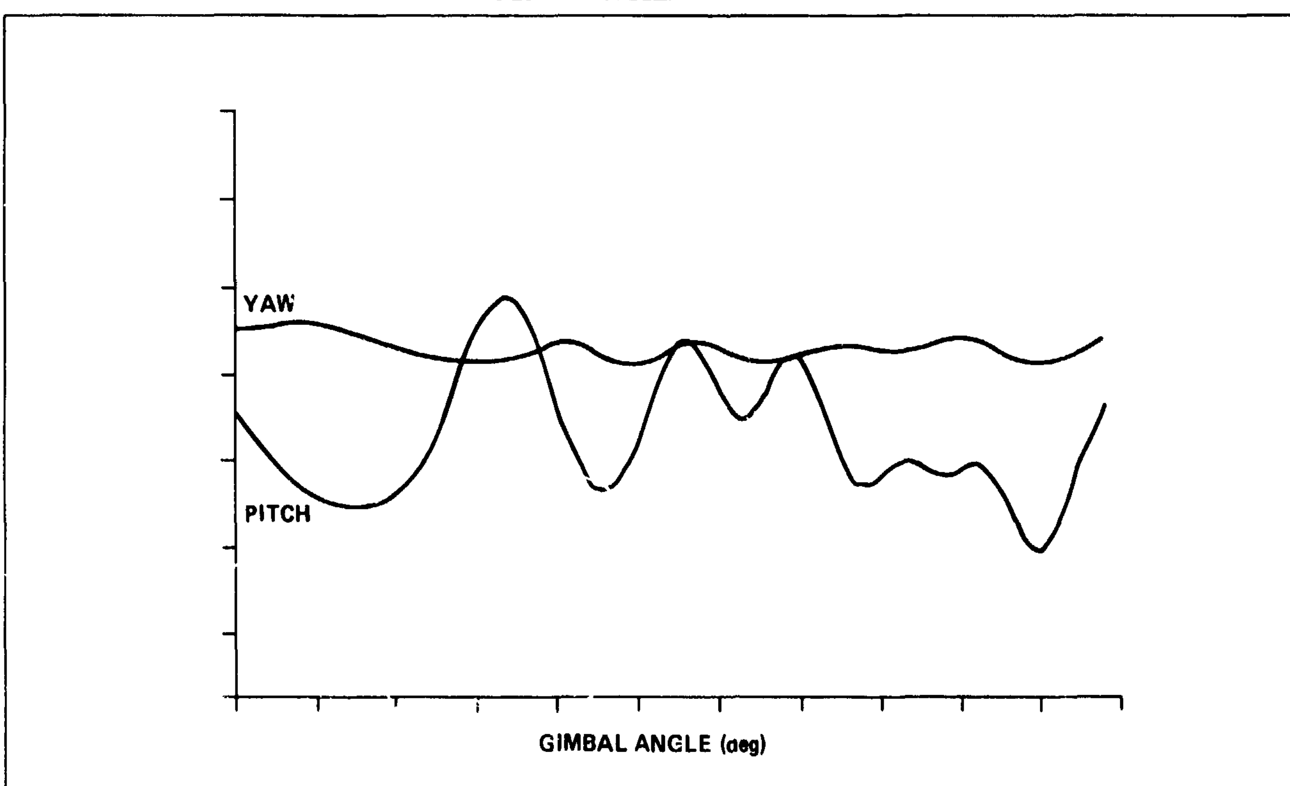

Figure 2. BSE vs Gimbal Angle with Computer Sampled Voltage Phase Corrections

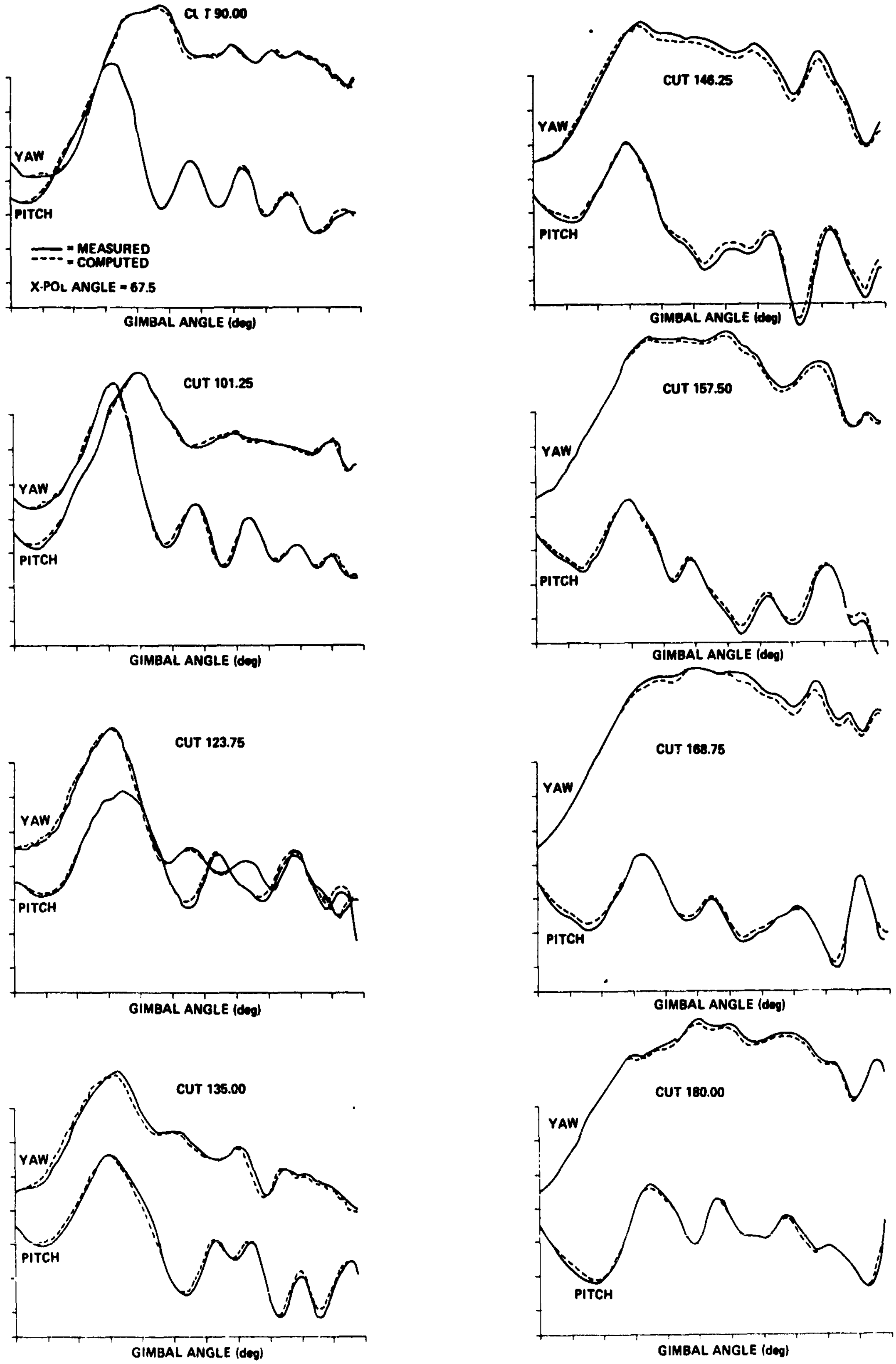

Figure 3. Computed and Measured Cross-polarization BSE Data